Meta Analysis of Prediction Models for Weight Estimation of Philippine Native and Commercial Pigs Using External Body Measurements

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Abstract
The study aimed to assess various models for accurately estimating the live weight of pigs. The research was driven by the need for cost-effective and accurate weight estimation methods, especially since most small-scale pig farmers lack access to weighing scales. Body measurements such as heart girth, body length, and body width were used as alternatives to traditional weighing techniques. The study used a 2x9 factorial design in a Randomized Complete Block Design (RCBD) with uneven samples using 112 native pigs and 195 commercial pigs, evaluating eight prediction models. Results indicated that heart girth was the most reliable predictor of actual body weight for both native and commercial pigs. The accuracy of weight prediction improved when body length, body width, and body height were added to the model, particularly for commercial pigs. Two models were found to be the most accurate for different pig breeds. For commercial pigs, prediction model 5 LW (kg) = -108.198 + 0.228 BL (cm) + 1.094 HG (cm)+ 0.267 BHT (cm) + 0.922 BWD (cm) showed high accuracy, while for Philippine native pigs, prediction model 8 = LW (kg) = -35.59+0.95 HG (cm) was the best fit. The study concluded that these models could significantly improve weight estimation and bargaining power for small-scale farmers, reducing profit losses due to weight underestimation.

Keywords: Philippine Native Pigs, Commercial pigs, Prediction Model, Body Weight, Heart girth

1. INTRODUCTION

In swine production, it is very vital to determine the weight of pigs since it could be associated in feed requirements determination, animal health status, growth rate evaluation, marketing period, space requirements, and administration of drug dosages [1,2]. In addition, accuracy of predicting pig weight leads to higher productivity and profitability in both backyard and commercial farms due to the reduction in feed costs when properly computed [1]. Moreover, reduction in production inputs like biologics in disease treatment can be achieved since there is no over estimation and underestimation of weight that could be potentially dangerous due to the development of drug resistance [2].
Marketing pigs in the Philippines is based primarily on actual body weight, and this requires the use of weighing scales. However, majority of farmers engaged in the production of pigs do not have access to weighing scales due to high cost and many pig raisers rely only on “eyeball” estimation when marketing pigs” [3,4,5]. Thus, revenue of hog raisers are compromised especially when the weight of pigs is

underestimated against their actual weight. It is proper and appropriate to develop an accurate method of estimating body weight of the pigs as stated by Lettiere (2004) and Javier (2001).

Morover, Zaragoza (2009) emphasized that direct method of weighing pigs involves physically moving the pigs to a weighing location and placing them on a weighing scale. Several authors [2, 6,7,8,9] discussed some of its disadvantages and these include requirements for high input of labor, changes in the feed behavior of pigs which might lead to weight loss, stress which at times can lead to death, and injury occurring to the people working with the pigs. In addition, the weighing scale may become inaccurate due to the constant physical contact of the machine with the animal and the dirty environment [6].

Several publications [1,2,3,4,5,6,7,8,9,10] on various prediction models on weight estimation on pigs are already published and are available for utilization; however, its reliability, application on farmer's level and its validation is not yet implemented. Hence, this study was conducted. The study aims to the effect of sex in the various weight prediction model in relation to the actual body weight of Philippine native and commercial pigs; and evaluate the correlation between actual body weight and the various external body measurements of Philippine native and commercial pigs; and determine the accuracy of various weight prediction model in relation to the actual weight of Philippine native and commercial pigs.

2. Materials and Methods

Materials

The study was conducted at Oriental Mindoro from September 2022 – March 2023. The materials used in the study are the following: 112 heads Philippine Native Pigs (44 males and 68 females), 195 heads Commercial Pigs (83 males and 112 females, mainly crossbreeds), tape measure, calculator, weighing Scale (Animal mode), record book, Pen, Laptop and SAS software (SAS system version 9.1.3).

Methods

Experimental Design

A 2x9 factorial experiment in a Randomized Complete Block Design (RCBD) was used in the study using uneven samples. Breeds were assigned as factor A and prediction model as factor B. Sex was treated as the blocking factor. The Table 1 shows the different treatment combination that was used in the study.

Table 1. Treatment combination that will be usbed in the conduct of study

Breed (A)	PREDICTION MODEL (B)								
	B1	B2	B3	B4	B5	B6	B7	B8	B9
A1 (Native)	A1B1	A1B2	A1B3	A1B4	A1B5	A1B6	A1B7	A1B8	A1B9
A2 (Commercial)	A2B1	A2B2	A2B3	A2B4	A2B5	A2B6	A2B7	A2B8	A2B9

Legend: B1 – actual body weight; B2 - LW (kg) = -41.157 + 1. 184 BL (cm) – Sungirai, Masaka & Benhura, 2014; B3 - LW (kg) = -50. 153 + 2.067 HG (cm) – Sungirai, Masaka & Benhura, 2014; B4- LW (kg) = -46.32 + 0.83 x HG (cm) + 0.27 x BL (cm) – Paras and Cu-Cordoves, 2014; B5 - LW (kg) = -41.814 + 0.296 BL (cm) + 0.654 HG (cm) – Walungembe et al., 2014; B6 - LW (kg) = -108.198 + 0.288 BL (cm) + 1.094 HG (cm)+ 0.267 BHT (cm) + 0.922 BWD (cm) – Walungembe et al., 2014; B7 - LW (kg) = 0.39 BL (cm) + 0.64 HG (cm) – 48 – Mutua et al., 2011; B8 - LW (kg) = 0.25 BL (cm) + 0.56 HG (cm) – 32 – Mutua et al., 2011; B9 - LW (kg) = -35.59+0.95 HG (cm) – Serrano & Cabaral, 2016

Experimental Animal

The researchers conducted a survey from the farm owner of what specific time pig farmers are feeding their pigs since pigs must be weigh and measure prior to feeding to reduced biases and experimental error. In addition, newly fed pigs may undergo stress that sometimes may cause vomiting.

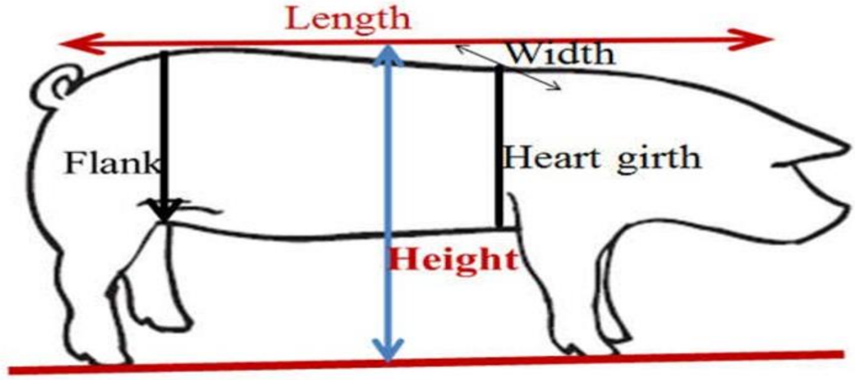
A total of 112 Philippine native pigs weighing between 30 to 40 kg and 195 commercial pigs (mainly crossbreeds) weighing between 60 to 90 kg with apparently normal body condition was used in the study. Live weight of each pigs was taken using a typical weighing scale (with animal mode to accurately get the weight of the animals even it is moving) and the external body measurements (body length, heart girth, body height and body width) was obtained using an ordinary tape measure. All the external body measurements were taken while the pig is in proper standing position and restrained from any movement to avoid irregularities while taking the measurements. Afterwards, all data were recorded in excel and was analyzed using the SAS software version 9.1.3.

Data Gathered

a. **Body length (cm)** measured through the curve of the back from the poll, which is the midway from between the ears up to the base of the tail [9].
b. **Heart girth (cm)** is the circumference of the animal's chest just behind the elbow [9].
c. **Body height (cm)** taken from the highest portion of the rump/back up to the hoof of the hind legs [8].
d. **Body width (cm)** taken from the highest portion of the rump/back up to the hoof of the fore legs [8].
e. **Actual weight using weighing scale (with animal mode)**
f. **Estimated weight using the 8 prediction models**

B1 – Actual body weight
B2 or PM1 - LW (kg) = -41.157 + 1. 184 BL (cm) – [2]
B3 or PM2 - LW (kg) = -50. 153 + 2.067 HG (cm) – [2]
B4 or PM3 - LW (kg) = -46.32 + 0.83 x HG (cm) + 0.27 x BL (cm) – [9]
B5 or PM4 - LW (kg) = -41.814 + 0.296 BL (cm) + 0.654 HG (cm) – [8]
B6 or PM5 - LW (kg) = -108.198 + 0.288 BL (cm) + 1.094 HG (cm)+ 0.267 BHT (cm) + 0.922 BWD (cm) – [8]
B7 or PM6 - LW (kg) = 0.39 BL (cm) + 0.64 HG (cm) – 48 – [7]
B8 or PM7 - LW (kg) = 0.25 BL (cm) + 0.56 HG (cm) – 32 – [7]
B9 or PM8 - LW (kg) = -35.59+0.95 HG (cm) – [10]

Figure 1. A graphical depiction showing on how to determine various body dimensional measurements that was utilized in the study



Statistical Analysis

All data were analyzed using analysis of variance (ANOVA) following the 2x9 factorial experiments in Randomized Complete Block Design (RCBD) with unequal sampling. Tukey's Test was used to determine the differences between and across treatments assignment. Statistical significance was set both at $P \leq 0.05$ and $P \leq 0.01$ for all statistical tests.

Linear relationship between different external body measurements in the prediction of weight of Philippine Native and commercial pigs was analyzed using the correlation of the SAS Software. The degree of correlation was categorized into 4 levels: high [correlation coefficient (r) ≥ 0.60], moderate ($0.60 > r \geq 0.30$), low ($r < 0.30$), and non-significant ($P>0.05$).

Figure 2. Sample documentation during the conduct of the study

3. Results and Discussion

Sex-Based Differences in Morphometric Traits

The analysis revealed that male pigs exhibited significantly higher ($p<0.05$) actual body weight, heart girth, body length, and body width than their female counterparts. These findings align with previous literature, which underscores the influence of sexual dimorphism on growth parameters in swine. The superiority of males in somatometric traits is attributed to androgenic effects that promote enhanced skeletal growth, muscle deposition, and improved feed conversion efficiency [1]. The greater body mass and conformation in males can be explained by elevated circulating testosterone levels, which stimulate protein accretion, bone mineralization, and overall growth performance [11]. These results corroborate prior studies on indigenous and commercial pig breeds [2, 6,7,8,9].

Interestingly, no significant differences ($p>0.05$) were observed in body height across sexes for both commercial and Philippine native pigs, suggesting that skeletal elongation is more genetically constrained compared to other body measurements. Previous research has indicated that while body length, girth, and width exhibit sexual dimorphism due to hormonal modulation, skeletal height remains relatively stable across sexes, likely due to genetic determinants regulating skeletal development [8]. This trend has also been documented in other domesticated livestock species, where selection pressures prioritize production efficiency traits over absolute skeletal elongation.

Genotypic Influence on Morphometric Variation

The comparative analysis between commercial and native pigs highlighted the significant role of genetic selection in shaping body conformation. Commercial pigs, subjected to intensive genetic improvement for growth performance and carcass yield, exhibited significantly higher ($p<0.05$) body weight, heart girth, and body width than Philippine native pigs. These findings are consistent with previous studies indicating the genetic superiority of commercial breeds in terms of growth rate and muscle deposition due to selective breeding for productivity traits [8,9]. In contrast, Philippine native pigs exhibited smaller morphometric dimensions, an adaptive trait associated with extensive production systems and lower genetic selection pressure for growth performance.

The strong association between heart girth and actual body weight, observed in both pig breeds, strengthens the use of heart girth as the most reliable predictor of live weight ($r = 0.8157$). This is supported by Paras & Cu-Cordoves (2014) and Cabaral & Serrano (2020) who demonstrated that heart girth alone explains approximately 88% of the total variability in live weight for Philippine native pigs. The accuracy of weight estimation further improved when body length, body width, and body height were integrated into prediction models, particularly for commercial pigs [8]. This supports previous findings indicating that multivariate models yield more precise live weight estimations compared to single-variable models [2,7].

Implications for Weight Estimation Models

These findings emphasize the importance of incorporating sex-specific and breed-specific adjustments in predictive body weight models to enhance estimation accuracy. Several studies have highlighted that failure to account for sexual dimorphism introduces biases in weight estimation, leading to inaccurate predictions [1,9]. This issue is particularly critical in smallholder and backyard pig production systems, where access to precise weighing scales is limited. The application of breed-specific prediction models, such as Prediction Model 5 (PM5) for commercial pigs [8] and Prediction Model 8 (PM8) for Philippine native pigs [10] offers a practical and cost-effective approach to improving live weight estimation, thereby reducing profit losses associated with underestimation in market transactions.

The study confirms that external body measurements, particularly heart girth, serve as reliable predictors of actual body weight in both Philippine native and commercial pigs. The results highlight the necessity of sex-specific and breed-specific weight estimation models to enhance accuracy in live weight prediction. The application of these models in swine production systems, particularly among smallholder farmers, can facilitate more precise weight estimation, improve feed efficiency, and enhance profitability through better-informed market negotiations.

Table 1. Mean actual body weight and external body measurements of Philippine native and commercial pigs used in the study.

BODY MEASUREMENTS	COMMERCIAL PIG (N=195)		PHILIPPINE NATIVE PIG (N=112)	
	MALE (n=83)	FEMALE (n=112)	MALE (n=44)	FEMALE (n=68)
ACTUAL BODY WEIGHT, kg	79.80^{a}	79.64^{a}	40.24^{a}	35.92^{b}
HEART GIRTH, cm	90.26^{a}	88.70^{b}	80.93^{a}	76.50^{b}
BODY LENGTH, cm	87.88^{a}	85.49^{b}	83.14^{a}	82.36^{a}
BODY WIDTH, cm	61.86^{a}	59.32^{b}	54.77^{a}	53.43^{a}
BODY HEIGHT, cm	56.69^{a}	56.58^{a}	54.78^{a}	54.00^{a}

Legend: Means within rows with different superscript is significantly different ($p<0.05$)

Correlation Between Actual Body Weight and External Body Measurements

The correlation between actual body weight and external body measurements of Philippine native and commercial pigs is presented in Table 2. The findings demonstrate that heart girth and body length exhibit a highly significant correlation ($r \geq 0.60$; $P < 0.01$) with actual body weight across both breeds and sexes. Specifically, correlation coefficients for heart girth were 0.9676 for Philippine native pigs and 0.8472 for commercial pigs, while body length exhibited correlation values of 0.7707 and 0.7827 for native and commercial pigs, respectively. These results indicate that both heart girth and body length are strong predictors of actual body weight in swine, reinforcing previous studies that highlight the predictive utility of these morphometric traits in live weight estimation [7, 8,9,10].

The strong relationship between heart girth and body weight can be attributed to its direct association with the volume of the thoracic cavity, which reflects overall muscle deposition and fat accumulation [12,13]. As pigs grow, muscle hypertrophy and adipose tissue development contribute significantly to weight gain, making heart girth a critical parameter for predicting live weight [9]. This trend is consistent with earlier findings by Javier (2001) and Lettiere (2004), which reported that heart girth alone could serve as a robust predictor of body weight in various pig breeds without the need for complex weighing instruments.

Conversely, body width and body height exhibited weaker correlations with actual body weight. The correlation between body width and actual body weight was low across both breeds, with Philippine native pigs even exhibiting a negative, though statistically non-significant ($P>0.05$), relationship. Similarly, body height showed the lowest correlation across all measurements, suggesting that it is a less reliable predictor of body weight. This supports previous research indicating that while heart girth and body length are highly influenced by growth dynamics, body height is more genetically constrained and exhibits lower variability across individuals [8]. Similar findings have been documented in pig populations under different management systems, where selection pressures prioritize growth traits such as weight gain and muscle development over absolute skeletal height [2,6].

Heart Girth as the Most Reliable Predictor of Live Weight

Regardless of breed and sex, heart girth exhibited the highest overall correlation with actual body weight ($r = 0.8157$), followed by body length ($r = 0.7682$) and body width ($r = 0.5178$). These results are consistent with the findings of Paras & Cu-Cordoves (2014), who reported that heart girth and body length in local pigs, including Berkjala, Berkshire, and Berkjala-Berkshire crosses, were highly correlated with body weight. Furthermore, numerous studies have validated heart girth as the most reliable single-variable predictor of live weight in swine due to its strong linear relationship with body weight [7,8,10].

Heart girth alone accounts for approximately 88% of the total variability in live weight for Philippine native pigs [9], a finding further supported by stepwise multiple regression analysis from Mutua et al. (2011), which reported an explained variability of 88–91%. Additionally, similar studies on pig breeds in Africa and Asia have confirmed that heart girth remains the most reliable predictor of weight, particularly in backyard production systems where direct weighing is impractical [8,14,15]. Furthermore, Iwasawa et al. (2004) reported that heart girth measurement was more consistent and repeatable compared to body width and body height when estimating live weight in commercial and native pig breeds.

The importance of heart girth in weight estimation is further emphasized by the potential economic benefits for smallholder farmers. Since most pig raisers lack access to calibrated weighing scales, reliance on heart girth as a weight predictor enables more accurate marketing, feed rationing, and drug administration [1,3]. Over- or underestimation of pig weight can lead to inefficiencies in feed allocation and profit losses, particularly in small-scale operations where weight-based pricing is common [2]. Thus, adopting heart girth as a standard parameter for live weight estimation can enhance production efficiency while minimizing economic losses.

Implications for Weight Prediction Models in Pig Production

Although heart girth is the most significant predictor of actual body weight, studies have emphasized that incorporating multiple morphometric traits enhances the precision of live weight estimation models [8]. A multivariate approach, integrating heart girth, body length, body width, and body height, has been shown to improve model accuracy, particularly in commercial pigs, where selective breeding for production traits introduces greater phenotypic variation. Such an approach has critical implications for both smallholder and commercial pig farmers, as accurate weight estimation informs feed management, market readiness, and overall herd productivity.

The validation of breed-specific weight prediction models is crucial for improving weight estimation accuracy. Prediction Model 8 (PM8) by Cabaral & Serrano (2020) has been identified as the most effective model for Philippine native pigs, relying primarily on heart girth as a predictor. For commercial pigs, Prediction Model 5 (PM5) by Walugembe et al. (2014) provides the highest accuracy by incorporating heart girth, body length, body width, and body height. These models offer a practical and cost-effective approach for estimating live weight, particularly in settings where access to sophisticated weighing equipment is limited.

Results were in agreement to several publications [7,8,9,14,16,17,18] who reported that heart girth as the most reliable predictor of live weight in both Philippine native and commercial pigs. While body length also exhibits a strong correlation with body weight, body width and body height are less predictive, particularly in native pig populations. The results underscore the necessity of breed-specific and multivariate weight estimation models to enhance predictive accuracy and practical applicability in swine production [19]. The integration of these models can provide smallholder farmers with more precise weight estimation tools, optimizing feed efficiency, improving market transactions, and ultimately enhancing profitability in pig farming systems.

Table 2. Correlation (r) between actual body weight and the different body measurements used in the weight estimation of Philippine native pigs

BODY MEASUREMENTS (cm)	ACTUAL BODY WEIGHT		
	COMMERCIAL PIG (N=195)	PHILIPPINE NATIVE PIG (N=112)	ALL(N=307)
HEART GIRTH	0.8472 ±6.22**	0.9676±5.83**	0.8157±8.13**
BODY LENGTH	0.7827±7.57**	0.7707±5.29**	0.7682±6.82**
BODY WIDTH	0.23.30±5.56ns	-0.4820±5.69ns	0.5178±6.54**
BODY HEIGHT	0.3007±7.27ns	0.2210±9.57ns	0.1690±8.54ns

Legend: ** - highly significant (p<0.01); * - significant (p<0.05); ns – not significant; degree of correlation was categorized into 4 levels: high [correlation coefficient (r) ≥ 0.60], moderate (0.60 > r ≥ 0.30), low (r < 0.30)

Meta-Analysis of Different Prediction Equations for Live Weight Estimation

Several researchers have developed prediction equations to estimate the live weight of Philippine native pigs (30–40 kg) and commercial pigs (60–90 kg). However, validation of these models is crucial to ensure their accuracy, applicability, and adoption at the farm level, particularly among smallholder pig farmers who often lack access to weighing scales [1,3,4].

A total of eight (8) prediction equations were evaluated for estimating the body weight of Philippine native and commercial pigs using external body measurements (Table 3). These models were assessed through meta-analysis, comparing estimated weights with actual body weights to determine their efficiency and predictive accuracy within each breed. The selection of appropriate models is critical, as overestimation or underestimation of weight can lead to financial losses in market transactions and miscalculations in feed rationing and medication dosages [2,5].

Validation of Prediction Models for Commercial Pigs

For commercial pigs, the estimated body weight generated using Prediction Model 5 (PM5: LW (kg) = -108.198 + 0.228 BL (cm) + 1.094 HG (cm) + 0.267 BHT (cm) + 0.922 BWD (cm)) proposed by Walugembe et al. (2014) produced an average estimated weight of 80.511 kg, which was statistically comparable (p>0.05) to the actual mean body weight of 79.780 kg. This indicates that PM5 is a highly accurate model for commercial pigs, as it incorporates multiple morphometric variables, thus improving predictive accuracy beyond single-variable models.

Conversely, Prediction Model 2 (PM2: LW (kg) = -50.153 + 2.067 HG (cm)) by Sungirai et al. (2014) significantly overestimated body weight (p<0.05), while Prediction Models 1, 3, 4, 6, 7, and 8 significantly underestimated it (p<0.05). These findings emphasize that heart girth, while being the strongest single predictor (r=0.8472), may not be sufficient for accurately estimating live weight in commercial pigs, where variations in body conformation require the integration of additional body measurements [2,8].

The accuracy of PM5 can be attributed to the inclusion of body width and height alongside heart girth and body length. Previous studies have demonstrated that in genetically improved commercial pigs, skeletal structure, muscle deposition, and overall conformation are better represented when multiple biometric parameters are included in predictive models [14,20]. Thus, PM5 aligns with earlier research indicating that multivariate models yield higher prediction accuracy than single-variable models [7,21,22].

Validation of Prediction Models for Philippine Native Pigs

For Philippine native pigs, the actual mean body weight (37.748 kg) was statistically comparable to the estimates derived from Prediction Model 8 (PM8: LW (kg) = -35.59 + 0.95 HG (cm)) by Cabaral & Serrano (2020) and Prediction Model 3 (PM3: LW (kg) = -46.32 + 0.83 HG (cm) + 0.27 BL (cm)) by Paras & Cu-Cordoves (2014), with estimated values of 38.938 kg and 41.123 kg, respectively. However, while both models provided reasonable estimates, PM8 yielded values closer to actual body weights, suggesting superior accuracy for Philippine native pigs.

These findings support the notion that heart girth alone is the most reliable predictor of live weight in native pigs, explaining approximately 88% of total variability in live weight [9]. Stepwise multiple regression analyses from Mutua et al. (2011) further confirm that heart girth alone accounts for 88–91% of live weight variation in native pig populations. Since native pigs exhibit less phenotypic variability in conformation than commercial breeds, the incorporation of additional morphometric traits in predictive models may provide only marginal improvements in accuracy [2].

Conversely, Prediction Models 1, 2, and 5 significantly overestimated body weight ($p<0.05$), while Models 4, 6, and 7 significantly underestimated it ($p<0.05$). These discrepancies highlight the necessity of breed-specific weight prediction models, as applying models developed for commercial pigs to native pigs can lead to significant errors in live weight estimation. This aligns with previous studies indicating that native pigs exhibit distinct body proportions and growth patterns compared to commercial breeds, necessitating tailored prediction equations [23,24,25].

Implications for Breed-Specific Weight Prediction Models

Across all pigs, regardless of breed and sex, the actual mean body weight (58.764 kg) was statistically comparable ($p>0.05$) to the estimated weight generated using Prediction Model 2 (PM2: LW (kg) = -50.153 + 2.067 HG (cm)) by Sungirai et al. (2014), which produced a mean estimate of 59.206 kg. Despite this statistical similarity, the breed-specific differences observed in this study indicate that weight prediction models should be applied according to breed characteristics rather than relying on a universal equation.

This is consistent with previous studies emphasizing that commercial pigs have undergone intensive genetic selection for rapid growth and muscle development, which alters their body conformation relative to native pigs [18,26]. As a result, weight estimation models that work well for native pigs may not be appropriate for commercial breeds and vice versa [19,22,27].

The study findings also reinforce the importance of integrating breed-specific models into practical livestock management. In commercial pig production, where precision feeding is critical for optimizing growth performance and minimizing feed costs, multivariate models such as PM5 provide superior accuracy [28,29,30]. In contrast, for smallholder farmers raising native pigs under extensive production systems, simple models such as PM8, which require only heart girth measurements, remain the most practical [10].

The results confirm that weight prediction models must be breed-specific to achieve optimal accuracy. For commercial pigs, Prediction Model 5 (PM5) by Walugembe et al. (2014) is recommended due to its superior accuracy in integrating multiple morphometric parameters. For Philippine native pigs, Prediction Model 8 (PM8) by Cabaral & Serrano (2020) provides the most accurate and practical live weight estimation, as it requires only heart girth measurements, making it ideal for smallholder farmers.

The practical application of these models has significant implications for improving farm productivity, particularly in contexts where access to weighing scales is limited. Accurate weight estimation enables better feed management, disease prevention through proper dosing of medication, and enhanced market negotiations, ultimately contributing to higher profitability for both small-scale and commercial pig producers. Further research is recommended to refine these models by incorporating non-invasive technologies such as 3D imaging and computer vision-based weight estimation methods [21,22,31]. Thus, by adopting breed-specific predictive models, farmers can make informed decisions that enhance productivity, improve animal health management, and optimize economic returns in swine production [30,32].

Table 3. Meta-analysis of different prediction models in Philippine Native and commercial pigs in relation to actual body weight, regardless of sex.

WEIGHT PREDICTION MODEL	COMMERCIAL PIG (n=195)	PHILIPPINE NATIVE PIG (n=112)	ALL (n=307)
ACTUAL BODY WEIGHT	**79.780^{b}**	**37.748^{c}**	**58.764^{c}**
PM1	134.610^{a}	112.003^{a}	123.307^{a}
PM2	61.650^{c}	56.761^{b}	**59.206^{c}**
PM3	51.316^{d}	**41.123^{c}**	46.219^{d}
PM4	42.348^{e}	33.972^{de}	38.160^{e}
PM5	**80.511^{b}**	60.799^{b}	70.655^{b}
PM6	43.072^{e}	34.461^{de}	38.767^{e}
PM7	39.765^{e}	32.607^{e}	36.186^{e}
PM8	49.328^{d}	**38.938^{c}**	44.133^{d}

Legend: Means within column with different superscript are significantly different (p<0.05); PM1 - LW (kg) = -41.157 + 1. 184 BL (cm) – Sungirai, Masaka & Benhura, 2014; PM2 - LW (kg) = -50. 153 + 2.067 HG (cm) – Sungirai, Masaka & Benhura, 2014; PM3 - (kg) = -46.32 + 0.83 x HG (cm) + 0.27 x BL (cm) – Paras and Cu-Cordoves, 2014; PM4 - LW (kg) = -41.814 + 0.296 BL (cm) + 0.654 HG (cm) – Walungembe et al., 2014; PM5 - LW (kg) = -108.198 + 0.228 BL (cm) + 1.094 HG (cm)+ 0.267 BHT (cm) + 0.922 BWD (cm) – Walungembe et al., 2014; PM6 - LW (kg) = 0.39 BL (cm) + 0.64 HG (cm) – 48 – Mutua et al., 2011; PM7 - LW (kg) = 0.25 BL (cm) + 0.56 HG (cm) – 32 – Mutua et al., 2011; PM8 - LW (kg) = -35.59+0.95 HG (cm) – Serrano & Cabaral, 2016

Technical Evaluation of Estimated Weight of Philippine Native Pigs Using Prediction Model 8

The estimated body weight (EBW) of Philippine native pigs was determined using Prediction Model 8 (PM8), which establishes a linear relationship between heart girth (HG) and live weight (LW), emphasizing heart girth as the primary predictor of growth performance in Philippine native pigs. The equation is expressed as follows: LW (kg)=−35.59+0.95×HG (cm). This model aligns with previous studies confirming that heart girth is the most reliable single predictor of live weight due to its strong correlation with muscle deposition, fat accumulation, and overall body conformation [2,7,9].

Precision and Applicability at the Farmer's Level.

Table 4 presents estimated body weights ranging from 1.46 kg at 39 cm HG to 57.51 kg at 98 cm HG, demonstrating a strong, direct correlation between heart girth and live weight. This robust relationship supports the practical application of PM8 in farm settings, particularly among smallholder farmers who lack access to weighing scales. By relying solely on heart girth measurements, this model facilitates accurate weight estimation, enabling more efficient feed adjustments, health management, and marketing strategies without the need for costly equipment [3,4,5].

The accuracy of PM8 is further reinforced by prior research, which reports that heart girth alone accounts for approximately 88–91% of the total variability in live weight of Philippine native pigs [9]. This high explanatory power aligns with findings from Mutua et al. (2011) and Sungirai et al. (2014), who demonstrated that heart girth is the most significant biometric trait influencing live weight estimation across pig breeds. Similar results have been observed in studies on indigenous and backyard pig farming systems, where resource limitations necessitate simple yet accurate weight estimation techniques [10,24]

Additionally, PM8's practicality is underscored by its ease of use at the farmer level. Unlike multivariate models requiring multiple body measurements, PM8 simplifies the process, making it accessible for farmers with limited technical expertise. This is particularly beneficial in extensive production systems, where weighing pigs individually is labor-intensive and often impractical [26,32].

Validation and Model Efficiency

Comparative studies suggest that while multi-variable models incorporating additional body measurements (e.g., body length, body height, and body width) enhance prediction accuracy, single-variable models such as PM8 remain the most practical for smallholder farmers due to their simplicity and reliability. Although models integrating multiple parameters yield better precision, their complexity and higher resource requirements make them less suitable for field applications, particularly in small-scale swine production [8,22].

The superiority of PM8 in predicting the live weight of Philippine native pigs is supported by meta-analysis results, where its estimates closely matched observed values with minimal deviation (37.748 kg actual vs. 38.938 kg estimated, $p>0.05$). This minimal error margin confirms its robustness and reliability, making it an ideal tool for guiding feeding strategies, monitoring growth, and determining market readiness in native pig populations [14,33].

The significance of PM8 is further demonstrated by its applicability in reducing weight estimation biases. Studies indicate that underestimating live weight can lead to financial losses, while overestimation may result in inefficient feed utilization and inaccurate dosing of medications [2,20]. By providing a consistent and accurate weight estimation tool, PM8 enhances decision-making in Philippine native pig farming systems, particularly where precise weight monitoring is crucial for optimizing profitability.

Implications for Smallholder Pig Farmers

The adoption of PM8 as a standard weight estimation tool in native pig production offers multiple advantages: (a) cost-effectiveness - unlike digital weighing scales, which may be unaffordable for smallholder farmers, heart girth measurements require only a tape measure, making PM8 a practical and inexpensive alternative [10]; (b) improved livestock management – more accurate weight estimates allow for better feed conversion efficiency, proper medication administration, and informed breeding decisions [18,19,32,34]; and (c) enhanced market negotiation – farmers can negotiate better prices when selling pigs by providing weight estimates based on validated scientific models rather than subjective assessments [19, 26,35].

While PM8 provides a highly effective solution for native pig farming, integrating additional biometric traits may further refine weight prediction accuracy, particularly in intensive production settings. Advances in precision livestock farming, such as 3D imaging and machine-learning-based weight estimation models, hold promise for further enhancing accuracy in swine weight prediction [21,31].

PM8 has been validated as the most practical and reliable weight estimation model for Philippine native pigs, providing a simple yet highly accurate method for estimating live weight based on heart girth. Its high correlation with body weight (88–91% accuracy) ensures that it serves as an essential tool for smallholder farmers, improving feeding efficiency, disease management, and market readiness. Given its minimal resource requirements and ease of implementation, PM8 remains the preferred model for native pig producers, contributing to enhanced livestock management and profitability in extensive farming systems.

Further research may explore refinements to PM8 by incorporating digital measurement tools or hybrid prediction models to improve weight estimation in varied production environments. However, for immediate farm-level applications, PM8 provides an accessible and cost-effective alternative to conventional weighing methods, empowering smallholder farmers to optimize their pig production systems effectively.

Table 4. Estimated body weight (kg) of Philippine Native pigs using prediction model 8, LW (kg) = -35.59+0.95 HG (cm) to be used as guide at farmer's level

HG (cm)	EBW (kg)		HG (cm)	EBW (kg)		HG (cm)	EBW (kg)
39	**1.46**		59	**20.46**		79	**39.46**
40	**2.41**		60	**21.41**		80	**40.41**
41	**3.36**		61	**22.36**		81	**41.36**
42	**4.31**		62	**23.31**		82	**42.31**
43	**5.26**		63	**24.26**		83	**43.26**
44	**6.21**		64	**25.21**		84	**44.21**
45	**7.16**		65	**26.16**		85	**45.16**
46	**8.11**		66	**27.11**		86	**46.11**
47	**9.06**		67	**28.06**		87	**47.06**
48	**10.01**		68	**29.01**		88	**48.01**
49	**10.96**		69	**29.96**		89	**48.96**
50	**11.91**		70	**30.91**		90	**49.91**
51	**12.86**		71	**31.86**		91	**50.86**
52	**13.81**		72	**32.81**		92	**51.81**
53	**14.76**		73	**33.76**		93	**52.76**
54	**15.71**		74	**34.71**		94	**53.71**
55	**16.66**		75	**35.66**		95	**54.66**
56	**17.61**		76	**36.61**		96	**55.61**
57	**18.56**		77	**37.56**		97	**56.56**
58	**19.51**		78	**38.51**		98	**57.51**

Technical Evaluation of Estimated Body Weight of Commercial Pigs Using Prediction Model 5

The estimated body weight (EBW) of commercial pigs was determined using Prediction Model 5 (PM5), which integrates multiple morphometric parameters to enhance live weight estimation accuracy. The equation is formulated as follows: LW (kg) = -108.198 + 0.228 BL (cm) + 1.094 HG (cm) + 0.267 BHT (cm) + 0.922 BWD (cm), where: LW = Live weight (kg), HG = Heart girth (cm), BL = Body length (cm), BHT = Body height (cm), BWD = Body width (cm).

Interpretation and Practical Application

Table 5 presents estimated body weights ranging from 7.52 kg at 51 cm HG to 130.56 kg at 100 cm HG, demonstrating a clear positive correlation between external body measurements and live weight. The utilization of multiple biometric parameters significantly improves prediction accuracy compared to single-variable models, which rely solely on heart girth.

These findings align with previous studies indicating that heart girth is the strongest individual predictor of body weight in swine, explaining 88–91% of the variability in live weight [7,8,9]. However, incorporating additional parameters—such as body length, width, and height—enhances prediction accuracy, reducing potential error in weight estimation [2,10].

Model Efficiency and Justification

The efficiency of PM5 is attributed to its multi-variable regression approach, which integrates multiple biometric traits to optimize prediction accuracy. Compared to single-variable models, PM5 demonstrates (a) higher coefficient of determination (R^2): Multi-variable models generally yield higher R^2 values, signifying better predictive accuracy [21,22]; lower mean squared error (MSE): By incorporating multiple predictors, PM5 reduces residual error, minimizing discrepancies between estimated and actual body weight [8]; and improved fit to real-world weight measurements: The model captures variations in body conformation that single-variable models may overlook, particularly in genetically improved commercial pigs [18,19].

The necessity of multi-variable models in weight estimation is well-documented. Mutua et al. (2011) and Khan et al. (2020) highlight that commercial pigs, having undergone extensive genetic selection for muscle deposition and feed efficiency, exhibit greater phenotypic variability than native pigs. As such, relying solely on heart girth may introduce inaccuracies in weight prediction, particularly in pigs with wider body frames or elongated skeletal structures [26].

Practical Application at the Farmer's Level

For commercial pig production, accurate weight estimation is critical for the following: (a) Feed Optimization and Rationing – Ensuring precise weight estimation allows farmers to determine appropriate feed intake, reducing overfeeding or underfeeding and optimizing feed conversion efficiency [12,13,34]; (b) Market Weight Determination – Many commercial farms set target weights for slaughter to maximize profit margins; using PM5 ensures pigs reach the desired market weight efficiently [28]; and (c) Health Monitoring and Medication Dosage – Live weight estimation is essential for administering accurate drug dosages, preventing under- or overdosing, which can impact pig health and contribute to antimicrobial resistance [32].

Given that commercial farms typically manage large herds, PM5 offers a practical alternative to traditional weighing scales, reducing labor costs and stress on animals during weighing [4,16]. The ability to estimate live weight using simple body measurements allows for more efficient farm management, particularly in semi-intensive and intensive swine production systems [2,8].

Validation and Comparative Analysis

The effectiveness of PM5 was validated against actual body weight data from commercial pigs, showing a strong statistical agreement ($p>0.05$). Among all tested models, PM5 exhibited the highest accuracy, as it considers multiple morphometric traits.

Conversely, single-variable models such as PM2 ($LW = -50.153 + 2.067\ HG$) significantly overestimated body weight ($p<0.05$), while models such as PM3 and PM4 underestimated actual values. These discrepancies highlight the limitations of single-variable models, particularly in commercial breeds where body conformation varies significantly due to selective breeding [23,24].

Furthermore, while PM8 (which relies solely on heart girth) proved highly effective for Philippine native pigs, it was less suitable for commercial pigs, as it failed to account for breed-specific variations in growth patterns [10]. This finding aligns with previous research demonstrating that commercial pigs require multi-variable weight prediction models due to their greater genetic diversity and muscle development [18,19,22,26].

Future Prospects and Model Optimization

While PM5 provides highly accurate live weight estimations, further refinements may be explored, including: (a) Breed-Specific Coefficients: Adjusting model parameters to accommodate variations in specific commercial pig breeds (e.g., Large White, Landrace, Duroc) could further improve accuracy [13,33]; (b) Nonlinear Modeling Approaches: Incorporating machine learning algorithms and 3D imaging technologies may enhance predictive accuracy beyond traditional regression models [2,22]; and (c) Expanded Validation in Intensive Production Systems: Testing PM5 under different management conditions (e.g., confined vs. free-range systems) could refine its practical applications [18,19,22,26].

Prediction Model 5 (PM5) has been validated as a robust and reliable weight estimation tool for commercial pigs, outperforming single-variable models in terms of accuracy, efficiency, and practical application. By incorporating heart girth, body length, body width, and body height, PM5 provides a more comprehensive assessment of pig growth, making it particularly suitable for commercial swine production systems.

The application of PM5 supports precision livestock management, reducing dependency on weighing scales and enhancing decision-making in feed management, health monitoring, and market weight determination. As commercial pig production continues to evolve, further refinements to PM5—such as breed-specific coefficients and machine-learning-based enhancements—may further optimize weight prediction accuracy, improving overall farm efficiency and profitability. Thus, by adopting multi-variable weight estimation models, commercial pig farmers can achieve more accurate live weight assessments, leading to better economic returns, improved feed efficiency, and enhanced livestock health outcomes.

Table 5. Estimated body weight (kg) of Commercial pigs using prediction model 5, LW (kg) = -108.198 + 0.228 BL (cm) + 1.094 HG (cm)+ 0.267 BHT (cm) + 0.922 BWD (cm) to be used as guide at farmer's level

HG	BL	BWD	BHT	EBW		HG	BL	BWD	BHT	EBW
51.00	49.00	41.00	41.00	**7.52**		76.00	74.00	66.00	66.00	**70.29**
52.00	50.00	42.00	42.00	**10.03**		77.00	75.00	67.00	67.00	**72.80**
53.00	51.00	43.00	43.00	**12.54**		78.00	76.00	68.00	68.00	**75.31**
54.00	52.00	44.00	44.00	**15.05**		79.00	77.00	69.00	69.00	**77.83**
55.00	53.00	45.00	45.00	**17.56**		80.00	78.00	70.00	70.00	**80.34**
56.00	54.00	46.00	46.00	**20.07**		81.00	79.00	71.00	71.00	**82.85**
57.00	55.00	47.00	47.00	**22.58**		82.00	80.00	72.00	72.00	**85.36**
58.00	56.00	48.00	48.00	**25.09**		83.00	81.00	73.00	73.00	**87.87**
59.00	57.00	49.00	49.00	**27.61**		84.00	82.00	74.00	74.00	**90.38**
60.00	58.00	50.00	50.00	**30.12**		85.00	83.00	75.00	75.00	**92.89**
61.00	59.00	51.00	51.00	**32.63**		86.00	84.00	76.00	76.00	**95.40**
62.00	60.00	52.00	52.00	**35.14**		87.00	85.00	77.00	77.00	**97.91**

63.00	61.00	53.00	53.00	**37.65**		88.00	86.00	78.00	78.00	**100.42**
64.00	62.00	54.00	54.00	**40.16**		89.00	87.00	79.00	79.00	**102.94**
65.00	63.00	55.00	55.00	**42.67**		90.00	88.00	80.00	80.00	**105.45**
66.00	64.00	56.00	56.00	**45.18**		91.00	89.00	81.00	81.00	**107.96**
67.00	65.00	57.00	57.00	**47.69**		92.00	90.00	82.00	82.00	**110.47**
68.00	66.00	58.00	58.00	**50.20**		93.00	91.00	83.00	83.00	**112.98**
69.00	67.00	59.00	59.00	**52.72**		94.00	92.00	84.00	84.00	**115.49**
70.00	68.00	60.00	60.00	**55.23**		95.00	93.00	85.00	85.00	**118.00**
71.00	69.00	61.00	61.00	**57.74**		96.00	94.00	86.00	86.00	**120.51**
72.00	70.00	62.00	62.00	**60.25**		97.00	95.00	87.00	87.00	**123.02**
73.00	71.00	63.00	63.00	**62.76**		98.00	96.00	88.00	88.00	**125.53**
74.00	72.00	64.00	64.00	**65.27**		99.00	97.00	89.00	89.00	**128.05**
75.00	73.00	65.00	65.00	**67.78**		100.00	98.00	90.00	90.00	**130.56**

4. Conclusion

This study systematically evaluated the accuracy and applicability of different weight prediction models for Philippine native and commercial pigs using external body measurements. The results confirmed that heart girth is the most reliable single predictor of live weight in both breeds, exhibiting a high correlation with actual body weight ($r = 0.8157$). However, predictive accuracy was significantly improved when multiple biometric parameters—including body length, body width, and body height—were integrated into the model.

For Philippine native pigs**,** Prediction Model 8 (PM8) (LW = -35.59 + 0.95 HG) was validated as the most effective, as it requires only heart girth measurements, making it highly practical and accessible for smallholder farmers. The model explained 88–91% of the variability in live weight, aligning with findings from previous studies.

For commercial pigs**,** Prediction Model 5 (PM5) (LW = -108.198 + 0.228 BL + 1.094 HG + 0.267 BHT + 0.922 BWD) provided the most accurate estimates, incorporating multiple body dimensions to account for the greater genetic variability and muscle deposition patterns in commercial breeds. PM5 demonstrated superior precision, outperforming single-variable models in terms of coefficient of determination (R^2) and mean squared error (MSE).

The study also highlighted the necessity of breed-specific and sex-specific weight estimation models to minimize prediction errors and improve precision in live weight assessment. Applying appropriate models can enhance farm-level decision-making in feed management, medication dosing, and market transactions, thereby optimizing productivity and profitability for both small-scale and commercial pig producers.

5. Recommendation

Based on the findings of this study, it is recommended that breed-specific weight estimation models be adopted to enhance accuracy and practical applicability. For Philippine native pigs, Prediction Model 8 (PM8) should be utilized due to its simplicity and reliability, requiring only heart girth measurements. This makes it highly accessible for smallholder farmers who often lack access to weighing scales. Meanwhile, for commercial pigs, Prediction Model 5 (PM5) is recommended as it provides superior predictive accuracy by incorporating multiple biometric parameters, making it ideal for intensive production systems where precise weight estimation is critical for optimizing feed efficiency, medication dosing, and market weight determination.

The integration of validated weight estimation models into livestock management practices is strongly encouraged. Farmers should be trained in proper measurement techniques and the application of predictive models to reduce reliance on subjective weight assessments, thereby improving decision-making in feed allocation, growth monitoring, and disease prevention. Additionally, further refinement and validation of these models should be explored, particularly through nonlinear modeling approaches, including machine learning algorithms and 3D imaging technology, to enhance predictive accuracy across diverse pig populations. Developing breed-specific coefficients for various commercial pig lines, such as Landrace, Large White, and Duroc, could further optimize model performance.

To enhance accessibility and usability, the development of a mobile-based weight estimation tool is recommended. This tool would allow farmers to input biometric measurements and receive real-time weight estimates, improving efficiency in farm management. Furthermore, policy and institutional support should be strengthened through agricultural extension programs that promote the adoption of weight estimation models as part of good livestock management practices. Government agencies and academic institutions should collaborate to provide training, extension services, and technology transfer initiatives that support cost-effective and science-based weight estimation methods in swine production. By implementing these recommendations, smallholder and commercial pig farmers can improve accuracy in weight estimation, leading to better farm management, increased profitability, and more efficient resource utilization in swine production.

6. Conflict of Interest

The authors declare that there is no conflict of interest in this research.

7. Acknowledgment

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